

Design and Fabrication of an Image Processing Based Autonomous Weapon

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Abstract: A wide variety of systems requires reliable security schemes ensured by different conventional methods. In most cases these methods are either too much costly or very slow for real world applications. This paper will discuss a new approach to provide the desired level of security by using an autonomous weapon which can detect and immobilize the safety hazard to the system using powerful image processing methods. The paper also summarizes its advantages, disadvantages, strengths, limitations, field of applications, future scopes along with related privacy concerns.

Keywords: Autonomous weapon, safety, image processing, Computer Vision.

I. INTRODUCTION

‘Autonomous weapon systems’ are defined as weapons that can independently select and attack targets, i.e. with autonomy in the ‘critical functions’ of acquiring, tracking, selecting and attacking targets[i]. Fully autonomous weapons can be enabled to assess the situational context on a battlefield and to decide on the required attack according to the processed information [ii]. In an Autonomous weapon a human operator can only intervene in the machine’s operations with a veto command [iii] – for instance, by activating an emergency stop button. In this case, autonomy is necessary because the available reaction timeframe precludes human interaction.

There has been rapid progress in civilian robotics in the past decade and military interest in increasing autonomy of weapon systems is driven by the potential for greater military capability while reducing risks to the armed forces of the user, as well as reduced operating costs, personnel requirements, and reliance on communications links.

Having great utility in modern military their use in the battlefield still is not in abundance due to some serious limitations such as differentiating between friendly and enemy troops. In advancement of technology along with many other methods, digital image processing based approach are very much promising; overcoming these limitations in great extent. Recent researches suggested that it is possible to differentiate between usual and unusual behavior, normal or abnormal incident even friendly or enemy troops by applying an image processing method [iv].

In most cases an autonomous weapon based on Image processing can be successfully employed to guard against the intruder or to restrict the unauthorized access in a no entry or limited access zone and in case of some other highly predictable areas.

II. METHODOLOGY

The thesis work is divided into following stages:

- Continuous image acquisition
- Comparing two consecutive image
- Getting the absolute difference between the images
- Conversion of the difference image to Grayscale image
- Enhancement of the grayscale image
- Reduction of noise and further enhancement
- Computation of areas of the disturbance
- Determination of the biggest disturbance
- Determination of the center point of the disturbance
- Sending the location of the disturbance to the Weapon control unit
- Setting the weapon according to the target location retrieved from the control unit After finalizing the target, the weapon starts shooting automatically.

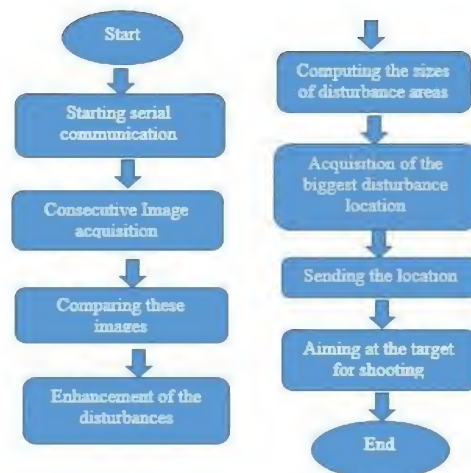


Fig. 1: Working Procedure of the system

III. COMPUTER VISION[vi]

Many processes as image threshold, dilation, erosion and analysis are used in dealing with the digital image [vi]. Digitizing an analog video signal is to convert the signal to be compatible with computer media to store and restore the signal; this is done by sampling and quantization. The value of the analog signal at each instant is converted to pixels, the smallest element of an image as shown in Figure (1). After the process of digitizing is completed, we have 2D of data constructed of

pixels, which contain the color information in each position of the image.

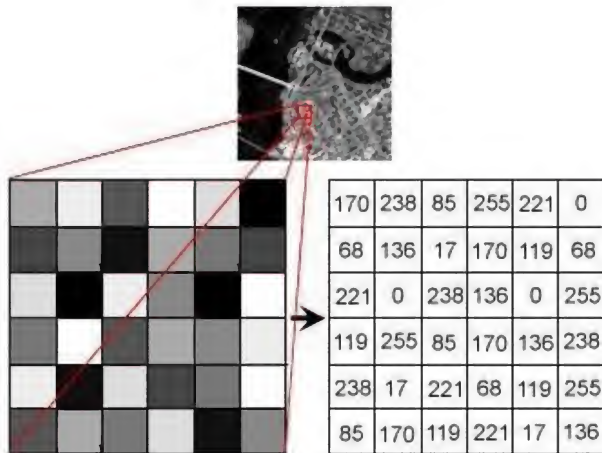


Fig. 2: Digital image representation by pixels [vii]

Each colored image is stored in three dimensional array $M \times N \times 3$, number 3 comes from creating three layers of the basics colors, Red, Green and Blue. These layers are composed to represent the true color image. Each colored pixel is composed of three values (red, green, blue), these values have the range between 0-255.

IV. BACKGROUND SUBTRACTION

This section describes the method for extracting moving targets from real time video stream. The approach is known as *Background Subtraction* [viii] which is the simplest method for detecting motion in a video frame. The main steps of detecting the target system are shown in Figure (2) are:

1. Frames differencing.
2. Detecting the moving target.

The idea is to take the absolute difference between a references stored background and a new frame which is grabbed from the camera. If no target is entered, the resultant pixel is expected to be zero value (difference result), else, if a target exists, the resulting pixels will give a value different than zero as shown in Figure (2).

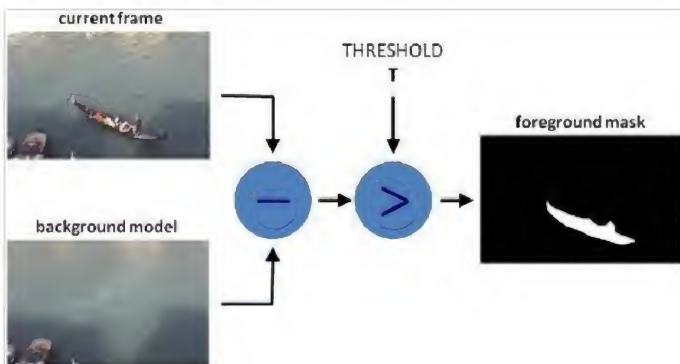


Fig.3: Background subtraction model [ix]

$$D = |IK - I - IK|$$

K: The frame number, I: frames, D: difference result

V. IMAGE ACQUISITION AND PREPROCESSING

Images are acquired using digital camera. The acquired image is in jpeg format taken from video which was in AVI format. The video frames are read in Visual Studio

C++ using the command `cvCaptureFromCAM()` provided by OpenCV library. After reading two consecutive images the absolute difference between them are found using `cvAbsDiff()` function. The resultant image from the difference between those images is now converted to gray image using `cvCvtColor()` function. The binary image from the gray image is found using `cvThreshold()` function. The noises present in the threshold image greatly reduced after dilation and erosion. As it is not possible to send all the locations at once, so the areas of the movement locations are computed and the biggest one is sorted out to send its location to the Arduino controller to control the weapon accordingly. Following figures show the result of image preprocessing operations in which some movement is detected in a closed room.

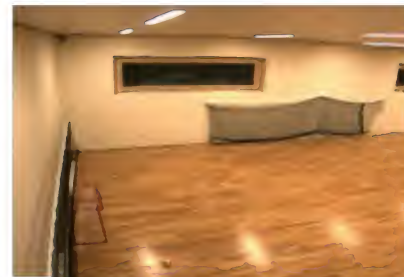


Fig. 4: 1st frame



Fig. 5. Grayscale image of 1st frame



Fig.6: 2nd frame



Fig.7. : Greyscale image of 2nd frame



Fig.8: Difference in image of the 1st and 2nd frame (enhanced).



Fig.9: The spot is rectangled

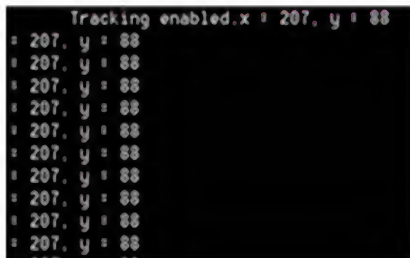


Fig.10: The disturbance location is sent to the weapon control system

VI. AUTONOMOUS WEAPON

The Autonomous weapon system (AWS) is suitable for deploying all direct fire weapons. Close range missiles (e.g. TOW, STINGER) have smart munitions with sensors that are effective over a narrow field of view. These weapons achieve optimum efficiency when deployed on AWS, because the weapon arming, uncaging, and firing are supported by electro-optic and other sensors that are more effective in terms of target discrimination and selection than the simplified sensors deployed in the missiles themselves. Directed energy weapons are simply adapted to the AWS. These weapons require extremely

small lead angles, and are independent of gravity and environmental factors, in terms of aim point. The AWS automatically discards all ballistic algorithms if deployed with directed energy weapons, at the same time introducing corrections for atmospheric refraction and firing delay (typically 1 –2 milliseconds). The atmospheric refraction corrections are required if the weapon wavelength and the sensor wavelength are not similar, and are particularly important for applications where the weapon and the target may be at different atmospheric densities. In this paper, mainly the method of employing toy guns are discussed as the other options are not available in public domain. It must however be emphasized that, once the threat is detected by the image processing unit and signal exported, the signal could be used to govern and direct a range of weapons. The control is weapon specific. Different control methods have to be applied for different weapon. This paper thus only shows how a nerf bluster toy gun can be governed and directed towards the threat successfully. The design of the nerf bluster toy gun is shown in fig. 10.



Fig.11: Nerf bluster toy gun

The details of this weapon with control unit is given in the following section.

VII. WEAPON AND WEAPON CONTROL UNIT

The weapon used, the nerf blaster toy is a direct fire type weapon which fires foam darts. The ammunition is manually loaded. A total of 12 darts or ammunition could be loaded at once. The direct fire weapon than can fire continuously by the trigger. Each time the trigger is pulled, one bullet is fired. The trigger is governed by one servo motor in this project. The trigger is attached to the servo by means of a string. When the servo rotates, the string gets wrapped up in the servo rotor and the trigger is pulled to fire one bullet. After the bullet is fired, the servo goes back to the original position. Releasing the pull on the trigger string. The following Fig. 11 shows the mechanical arrangements made, to allow the autonomous weapon to move and acquire targets.

The weapon control unit consists of mechanical parts, which are:

1. Side brackets,
2. Servo holders,
3. Upper base and
4. Lower base

The side brackets allow for the mounting of the weapon. They are directly attached to the weapon which hold the weapon and allow for rotation of the weapon by servos to change direction of weapon aim in the y-axis. The servo holder is the vertical plate where the servo for y-directional aim changing is placed



Fig. 12: 3D Design of the Autonomous Weapon

and held. This must be strong and able to resist torque provided by the servo. The upper base rests on the pan servo and it totally contains the weapon, side brackets and the servo holders. The whole weapon system is mounted on the lower wooden base.

And the electronics equipments are:

- i) Servo motors
- ii) Arduino Mega 2560 microcontroller board
- iii) Power supply unit
- iv) Power distribution board
- v) Program to run the motors precisely

There are mainly three servo required for controlling the weapon smoothly; one for the pan movement, other for the tilt movement and the rest one is employed as trigger motor. In this case, standard 180° rotation servo motors were used. Arduino Mega controller is employed both to receive the signals from the image processing computer and to guide the weapon as it is programmed.

Power supply unit is required to power the Arduino board and onboard servo motors. Operating voltage of Arduino is 5V and standard servo motors can operate between 6V to 12V.

Power distribution board ensures the distribution of power to the different component according to their requirements.

And the most important part of the control system is Arduino code which receives signal from the image processing unit and guides the weapon accordingly.

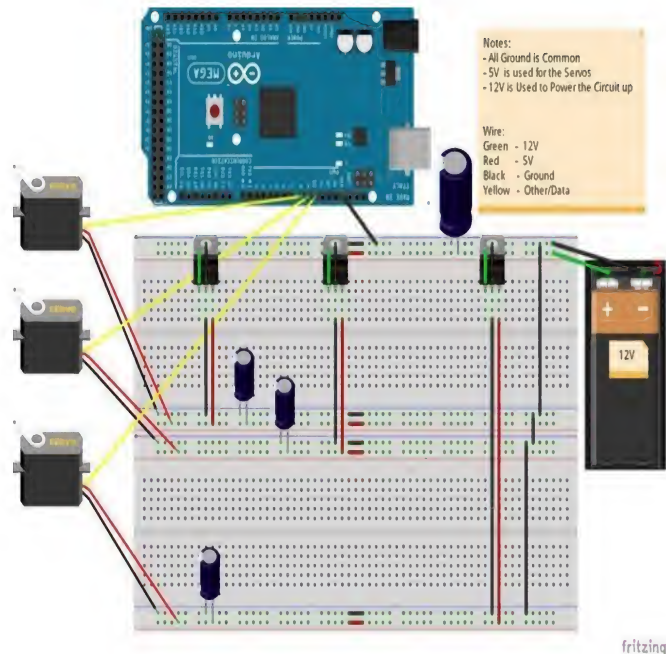


Fig. 13: Electronics arrangement

VIII. CONCERNS

Despite the promise it holds, like everything else, image processing based autonomous weapons also come with some concerns. Before it is employed in any place, it has to be made absolutely sure that the security works 100% accurately. There is very little room for error given the lethal nature of the security. It is also to be made sure that only the military and the government has access to it and that it does not fall on wrong hands. To stop misuse, the security has to be made hack resistant. At no cost, should it ever end up on civilian's hand, the consequences might be catastrophic. Wherever installed, it must be duly informed of the security's presence so that unwanted death or harm does not occur. The security must only be used only in case of 24 hour surveillance, highly restricted areas or in areas where human surveillance is not good enough.

IX. CONCLUSION

Making an autonomous weapon and employing it in real world applications is challenging due to the fact that the image processing techniques are not as fast as it requires in detecting the targets in real time. These techniques normally track slow moving objects and most of the cases the environmental conditions have greater impact on the final detection. The sizes and shapes are quite uncertain in real world applications. In addition, the processing speed is strongly affected when higher resolution and frame rate cameras are used.

In this thesis, we used background subtraction, which is one of the simplest techniques available, to reduce the processing time.

Despite the existing limitations [x] such as the strict requirement of proper lighting and slow motion, the result showed that background subtraction is a feasible solution for detecting motion and acquiring target for the autonomous weapon.

There are some issues remaining for future work. Currently, parameters associated with the technique need to be set up manually. They need to be reset when the camera is moved to a different location. In the future, a mechanism which can automatically configure these parameters can be constructed. To compromise with the complex and unstable environments, a more robust technique needs to be developed which is able to detect and track efficiently in both indoors and outdoors environments. In the future, we hope to make improvements in the state estimation in order to reduce the chances of needing to search the entire image.

Another avenue for future work involves discriminating between normal and abnormal motion of objects based on behavior analysis [xi].

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